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A study of some of the physical and chemical factors affecting the efficiency of WASHING TOMATOES

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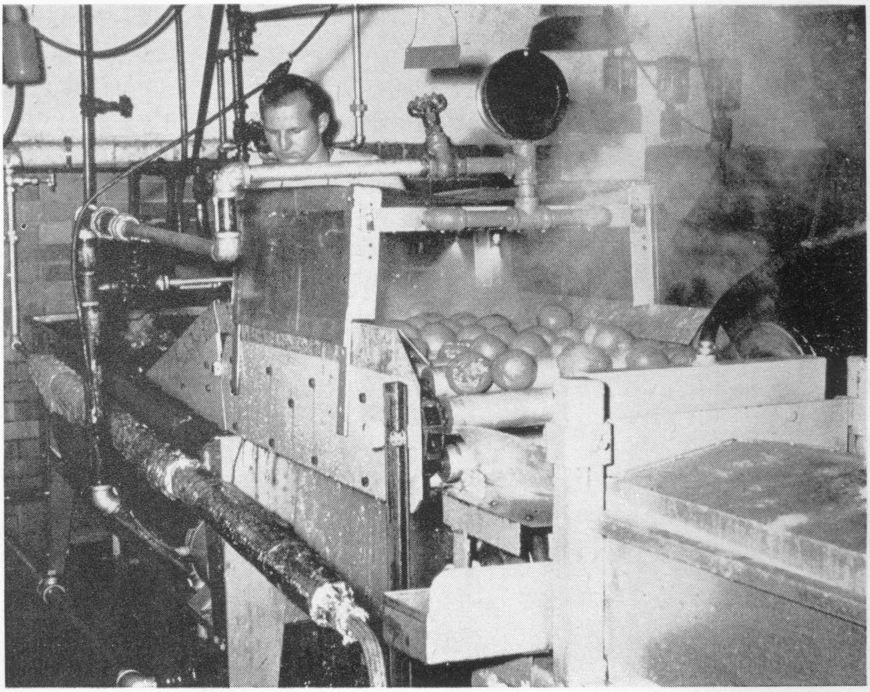

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A STUDY OF SOME OF THE PHYSICAL AND CHEMICAL FACTORS AFFECTING THE EFFICIENCY OF WASHING TOMATOES

WILBUR A. GOULD, J. R. GEISMAN and J. P. SLEESMAN [1, 2]

The production of high quality canned foods is dependent upon the use of high quality raw materials, and the control of processing variables. Tomatoes grown for canning are subject to attack by insects and microorganisms which could lead to decomposition. Insect damage to the raw stock is most serious as it may be a source of contamination in the finished product. Of the insect pests encountered, the control of *Drosophila* flies is probably one of the most serious problems confronting the tomato processor today.

On July 20, 1951, the Food and Drug Administration announced that "rot and extraneous matter are not permitted in tomatoes to be canned or made into tomato products (9)." Shortly after the issuance of this regulation, canned whole tomatoes from the Jaqua Canning Company were seized. This hearing proved to be a "test" case for the seizure of tomatoes and tomato products containing *Drosophila* eggs and larvae. During the testimony it was pointed out that "*Drosophila* eggs and maggots present in food for human consumption constitute filth within the

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[1]The authors wish to express their gratitude and appreciation to the following individuals, companies and associations for their contributions to this study:

A. W. N. Brown, M. W. Austin, D. G. DeWeese, D. R. Davis, C. M. Icenogle, Charles Bowen, Janet Lowman and Judith Lowman of the Ohio Agricultural Experiment Station and The Ohio State University and L. S. Henderson, U. S. Department of Agriculture.

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C. Charles Mahoney, National Canners Association and William C. Creamer, Chairman, Research and Marketing Committee, Ohio Canners Association.

[2]This study was initiated in 1955 as a contract project between the U. S. D. A. and the Ohio Agricultural Experiment Station.

purview and meaning of the Federal Food, Drug and Cosmetic Act (1)." This means that a quality conscious packer must have some means of removing any *Drosophila* contamination present.

The approach to *Drosophila* control may be divided into three phases:

1. Field control—Specific procedures recommended by the National Canners Association (NCA) and others should be followed.
2. Harvesting and handling practices—Avoid rough handling. Prevent contamination from the field to the receiving platform by using clean lugs and hampers and preventing long holding periods from harvest to processing. Control programs around the plant may be required.
3. In-plant control or practices within the plant that aid in the control or removal of eggs and larvae.

This study and the recommendations in this bulletin are concerned with the latter phase.

The objectives of this study therefore were:

1. To evaluate the effect of specific types of washers and washing techniques for the removal of *Drosophila* eggs and larvae from contaminated tomato fruits.
2. To determine the value of using wetting agents for the removal of *Drosophila* eggs and larvae from contaminated tomatoes.

REVIEW OF LITERATURE

The literature revealed little published information concerning in-plant control of *Drosophila* and the factors involved in the washing of vegetables for processing. However, much work has been done by the NCA in cooperation with several state experiment stations and processors on the field control of *Drosophila*. Although the field control precautions are not within the scope of this Bulletin, it would seem that a knowledge of the life cycle of the *Drosophila* and periods of highest egg laying activity would be important to the quality control technologist and the tomato processor. This information could be helpful in determining if and when heavy infestations might be expected.

Drosophila flies, also known commonly as vinegar gnats, fruit flies, sour flies and pomace flies, reproduce rapidly requiring ten to twenty days for one generation (4, 5). This insect goes through four stages of development, egg, larva, pupa and adult (see Figure 1).

The egg is unique in that it is easily identifiable by the two or four tube shaped structures on one end. They are pearly white, elongate-elliptical and about one-fourteenth inch in length. Eggs may be deposited by the female shortly after fertilization or may be held in the uterus during the early stages of development.

Larvae or maggots are cream colored when first hatched and are about one-thirtieth inch in length. They shed their skins three times and when mature, they are approximately one-fourth inch long. The larval period varies from four to eight days depending on the temperature.

Pupae, at first white, turn brown in four to five hours. They are approximately one-sixth inch long and have two breathing tubes at one end. This stage lasts four to five days at 75° to 85° F.

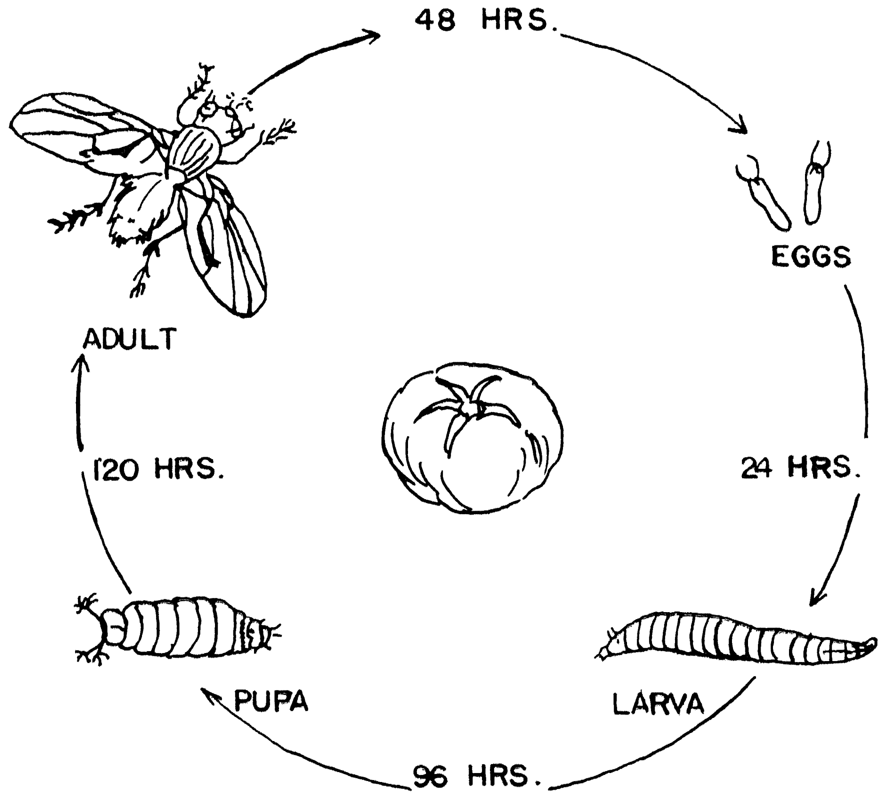


Fig. 1.—Life Cycle of the Drosophila (Redrawn from Dorst & Knowlton (5))

The adult is a yellowish, clear winged fly about one-eighth inch long. They prefer to feed on and are attracted to fermenting or yeasty material. However, tests have shown that the exposed flesh of firm, ripe tomatoes is preferred as a place for the fly to deposit its eggs over either the flesh of green tomatoes or tomatoes which have started to decompose (2). A female may begin laying eggs the second day of adult life and continue at a rate of approximately 26 eggs a day for a period up to five months. A single fly may lay as many as 2,000 eggs (2).

The cracks where the eggs are deposited may be either natural growth cracks or those caused by mechanical means (1).

The fly is most active in the middle to latter part of the tomato growing season. Egg deposition is heaviest during the period from 6 to 8 a m. and 4 to 8 p. m., depending upon light intensity and temperature. During these two periods egg laying is 25 to 35 times greater than during the rest of the day (2, 4).

Besides light intensity and temperature, other factors are known to affect fly activity. Wind velocities above 15 miles per hour curtail flight but not activities such as feeding, mating and egg laying. Evidence indicates that high humidity is favorable to fly activity and ovipositing (2).

MATERIALS AND METHODS

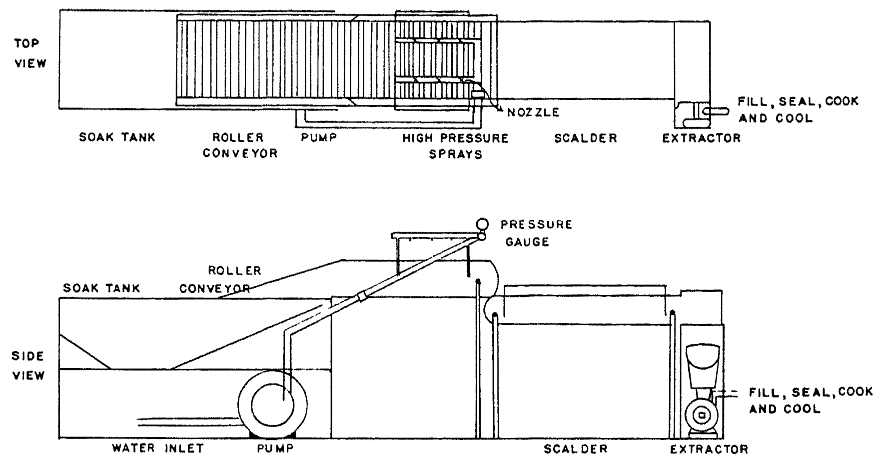
There have been two phases of this work. One was strictly in the Horticultural Products Pilot Plant at the Ohio State University, Columbus, Ohio; and the other phase was on a production line basis in cooperation with a commercial tomato processor.

Pilot Plant

Tomatoes used in the pilot plant grew on the Ohio State University Farm. The tomatoes were harvested, roughly handled, and were held for one to five days before processing.

The tomatoes were randomly separated into 100 pound lots. They were given various soaking and rinsing treatments (see Figures 2, 3 and 4).

This operation was followed by a 45 second scald. Juice was then extracted by a Langsenkamp Model B extractor. The juice was pasteurized in two ways. It was heated to 242° F. in a Walker-Wallace Plate Heat Exchanger or heated to 190° F. in an open kettle which contained a heating coil. If the juice was flash pasteurized, it was then filled into cans, sealed under 15 p.s.i. steam flow closure, coded, inverted for three minutes and then water cooled to 100° to 105° F. The juice heated to 190° F. was filled into cans. The cans were then exhausted



SOAK TANK	CAPACITY – 83 GALS
PUMP	CENTRIFUGAL VARIABLE SPEED
ROLLERS	3" DIAMETER
NOZZLES	18SQ 6.5GPM AT 130 PSI
SCALE	1/2" = 1'

Fig. 2.—Pilot Plant Flow Sheet

for four minutes, sealed under 15 p.s.i. steam flow closure, coded, inverted, processed at 220° F. for 30 minutes and water cooled to 100° to 105° F.

Commercial Tomato Processor

Tomatoes were obtained from "growers". Their fruits were from loads of heavy fly activity or rough handled hampers that were held for one day.

At the commercial plant 80 to 100 hamper lots (33 lbs. each) were used. Tomatoes were dumped onto a roller conveyor, soaked and spray rinsed. They were then chopped and juice was extracted. The juice was then concentrated to 12 to 14 percent solids. After thoroughly stirring, a sample of this pulp was removed, filled into cans and the cans were closed with a semi-automatic sealer. The cans were inverted and then air cooled to 100° to 105° F.

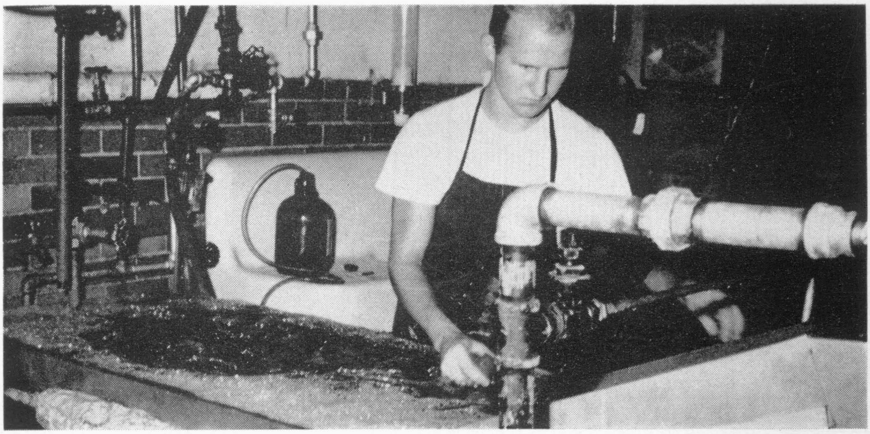


Fig. 3.—The soak tank as used in the pilot plant. Both detergent and chlorine were added to this phase of the washing operation. Note the small amount of foam on the soak water.

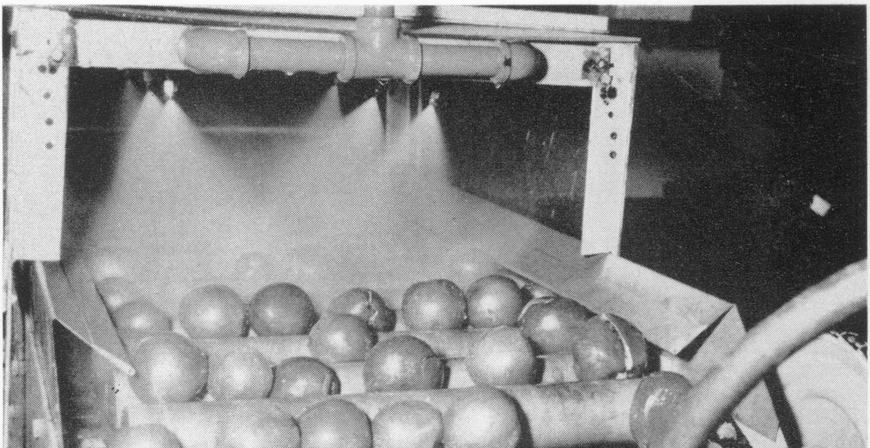


Fig. 4.—The high pressure spray rinsing operation. The tomatoes were rotated under the high pressure sprays, thus exposing all area to the rinsing operation.

Washing Techniques

In this study, washing techniques have been divided into two aspects. These are (1) the effect of mechanical or physical factors and (2) the value of detergents and chlorine or chemical factors.

Mechanical or Physical Factors

The first phase of the washing operation was the soak period. In this phase three factors (time, temperature and agitation) were considered.

Agitation was accomplished in two ways: either live steam, which also served as a means of heating the water, or air under pressure.

A series of time-temperature variations were made by varying the water temperature in ten degree increments from 70° F. to 150° F. and the soak time for one, three and five minutes. A three minute soak at 140° F. was the maximum as at this time-temperature the tomato skin began to slip.

In the laboratory, a 70° F. soak for three minutes was considered as the check lot. However, on the commercial line an 80° F. soak for three minutes was used as the check. This soaking period was the regular operation used in the commercial plant. Studies at the processing plant consisted of those practices which appeared to give good reduction of fly eggs, maggots, etc. in the pilot plant.

The second phase of the washing operation was the spray rinse period. Three factors were considered: (1) rotation of the tomatoes, (2) number and type of nozzles and (3) spray pressure and volume of water.

A number of nozzles were tested including those of the fullcone, flooding and knife types. Variations were made in the height of the nozzle above the tomatoes from four to eight inches. Through these variations differences in impact at the fruit surface and the area covered by the spray were obtained.

Several different sizes of nozzles were tested at various pressures to determine which one produced an adequate particle size to accomplish the desired washing. Particle size varied from a mist to coarse globules depending upon the pressure and nozzle orifice. The distance between nozzles was determined by the type of nozzle and spray pattern. Four to six nozzles were used in the pilot plant and six to thirty nozzles were utilized in various combinations on the commercial line.

Pressures were varied from 50 to 150 p.s.i. by means of a variable speed centrifugal pump. The volume of water used depended upon the type of nozzle and pressure.

Rotation of the tomato was accomplished with a roller conveyor. The number of revolutions necessary for adequate washing was determined. The length of conveyor needed was dependent on the size of rollers and conveyor speed.

Detergents and Chlorine or Chemical Factors

Detergents were studied from the standpoint of an additive when needed. They were not necessary at all times as some eggs and larvae could be removed by soaking and rinsing.

Ten detergent formulae were screened in the pilot plant from the standpoint of foaming, removal of eggs, larvae and other contaminants and effect on the pH of the soak water and of the tomato juice. These formulae are shown in Table 1. The promising ones were than further evaluated on the commercial line.

TABLE 1.—Detergents and Formulated Washing Compounds Screened in the Pilot Plant

1	Sterox AJ	8	Alkaline Detergent #3 Sterox CD Crystal Caustic Dry metasilicate of soda Tri-polyphosphate
2	Sterox CD		
3	Santomerse		
4	Anionic Wetting Agent		
5	Nonionic Wetting Agent		
6	Alkaline Detergent #1 Sterox CD Tri polyphosphate Nalopon B F C	9	Hydroxy acetic acid and Nonionic Wetting Agent
7	Alkaline Detergent #2 Sterox CD Dry metasilicate of soda Tri polyphosphate	10	Tomato Washing Detergent Sodium Tri polyphosphate Sodium Metasilicate Soda Ash Sterox CD

Concentrations were varied from 0.1% to 0.5% active ingredient. The results of the 1955 season tests were used as a guide in formulating a detergent that was studied in the 1956 season.

Sodium hypochlorite solution was proportioned into the soak water in the laboratory to control possible thermophilic build-up. Various concentrations from 0.0002% to 0.01% were used. On the production line, all lots were given a chlorinated spray rinse.

Counting Method to Determine Efficiency of Washing

As an index of insect contaminant removal, an egg and larva count was made. Since the official AOAC method requires much time, special techniques and equipment, a rapid, reproducible method would appear to be more desirable from the standpoint of both the processor and analyst. A method of this type has been developed (8). Equipment utilized in this method is shown in Figure 5. The detail of the procedure are as follows:

Tomato Juice:

1. Thoroughly shake unopened container.
2. Remove 100 ml. aliquot.
3. Pour approximately 50 ml. of aliquot onto an 18.5 cm. "sharkskin" filter paper seated in a #5 Buchner funnel. Spread sample evenly and thinly on paper and use a filter pump or water aspirator to remove moisture. Repeat this operation with the rest of the sample. Rinse the graduate cylinder with water and add to last paper.

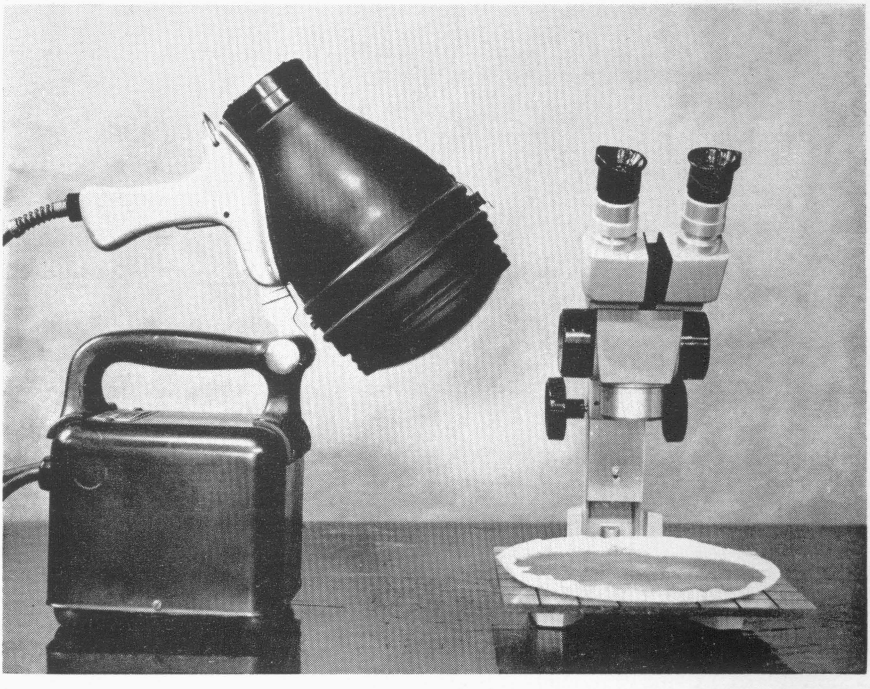


Fig. 5.—Drosophila fly egg equipment showing filter paper ready for counting with the aid of a 100 watt ultra-violet light source and stereoscopic microscope.

4. Place filter paper on a previously lined glass or plastic plate.
5. Using a long wave ultra-violet light source of 100 watts and a Stereoscopic wide-field microscope, examine the papers for eggs and larvae. Eggs and larvae appear blue-white in ultra-violet light and may be easily identified. Any other fluorescing filth present may also be detected.

Tomato Pulp and Paste:

1. Prepare sample in the same manner as juice.
2. Remove 100 ml. aliquot.
3. Dilute with an equal amount of hot (130° F.) water. (With paste use 200 ml. of hot water.)
4. Follow steps 3, 4, 5 and 6 for juice while material is hot.

Tomato Catsup:

1. Prepare sample in same manner as juice.
2. Remove 100 ml. aliquot.
3. Dilute with 250 ml. of boiling water.
4. Follow steps 3, 4, 5 and 6 for juice while material is hot.

Unprocessed Tomato Juice:

Use the same procedure as for processed juice except pour only 34 ml. of raw juice onto filter paper. Use three papers instead of two.

RESULTS AND DISCUSSION

The results of this study of washing techniques are presented by considering the effect of each operation, soaking, spray rinsing, and the value of detergents and chlorine as additives to the soak water.

A. Soaking Operation

It has been found that agitation of the tomatoes during the soaking period aids in the removal of *Drosophila* eggs and larvae and other contaminants. Agitation may be accomplished in the flume or soak tank by means of air under pressure or live steam.

The results of the soak time-temperature studies (Figure 6) indicate that as temperature was increased, egg removal was increased. The same relationship existed with the length of the soaking period. However, at 140° F. for three minutes considerable slipping of the peel occurred. An average reduction in eggs and larvae of 48 percent (significant at the .01 level) was obtained at 130° F. for three minutes. Although a greater reduction was obtained at 120° F. for five minutes, from an economical viewpoint this period might be too costly and time consuming. Therefore, soaking at 130° F. for three minutes appeared to be most nearly ideal.

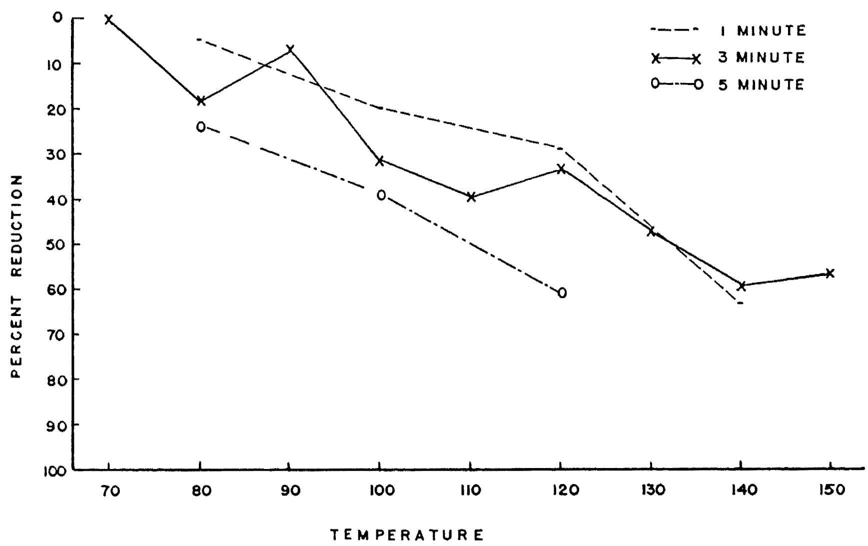


Fig. 6.—Effect of soak time and temperature on drosophila egg reduction.

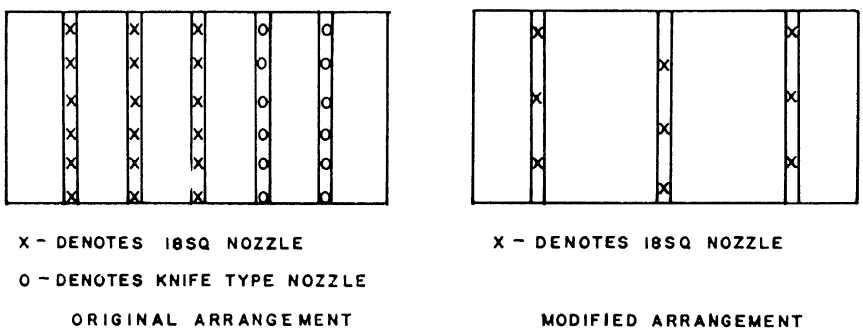


Fig. 7.—Manifold arrangement for high pressure sprays on commercial line.

B. Spray–Rinse Operation

In order to study the factors in the rinsing operation a manifold was constructed as shown in Figure 7. It was placed in such a manner that water from the spray did not flow into the soak tank. This eliminated some of the dilution of the detergent and chlorine concentration of the soak water. To accomplish complete coverage of the tomato surface with the rinse, a roller conveyor was used. The tomatoes made two complete revolutions while under the manifold.

Of the nozzle types tested, the one which appeared best was the full cone type that gave a square spray pattern. This nozzle (3/8 GG 18SQ-Spraying Systems Company) produced the proper particle size to accomplish the desired washing (3). The knife type nozzle produced a cutting spray which removed most of the soft tomato tissue. However, there was more tomato waste with this type than with the full cone type. The flooding nozzle did not aid in the removal of soil or contaminants, but merely wet the surface of the tomatoes.

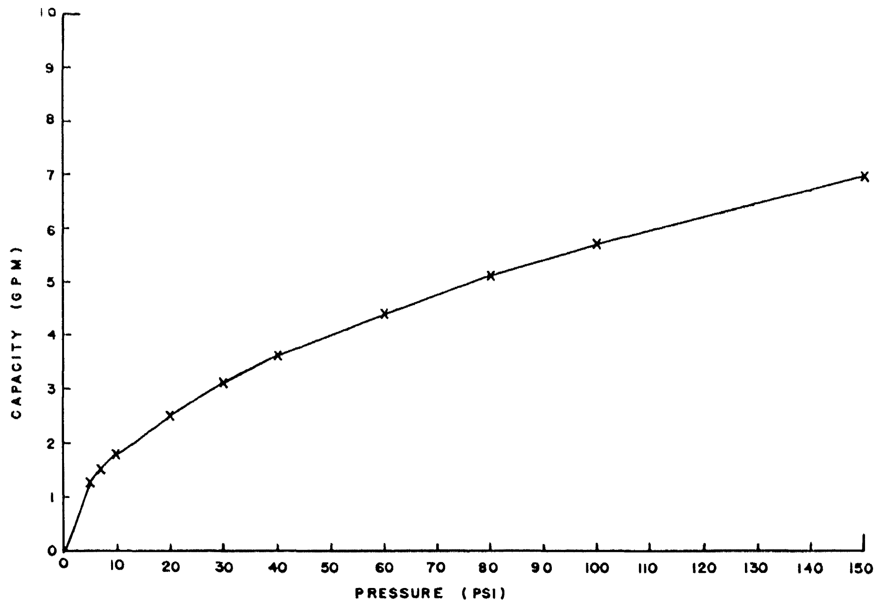


Fig. 8.—Relationship between pressure and capacity (volumes) for a fullcone type nozzle (GG 18 SQ) from spraying systems catalog No. 24.

The number and height of the nozzles were varied in order to obtain optimum coverage and impact at the fruit surface. Coverage and impact were also dependent upon the pressure and type of nozzle used. However, nine of the square spray nozzles at a height of seven inches above the rollers appeared to give optimum coverage on a 40 inch conveyor and optimum spray impact at the fruit surface.

In the rinsing operation, the pressure used was probably the most important factor. Impact, coverage, particle size and volume of water used depended upon the pressure. The relationship (see Figure 8) of pressure to volume of water was linear within the limits of this study. In these studies the data indicate that as pressure was increased, egg and larva removal was increased (see Figure 9). However, there was also an increase in the amount of tomato waste. At 150 p.s.i., waste and water volumes were too large to permit practical application. A pressure of 130 p.s.i. appeared most nearly ideal. At this pressure, the above mentioned nozzle delivers approximately 6.5 gallons of water per minute. Furthermore, when placed seven inches above the rollers, one square foot coverage was obtained.

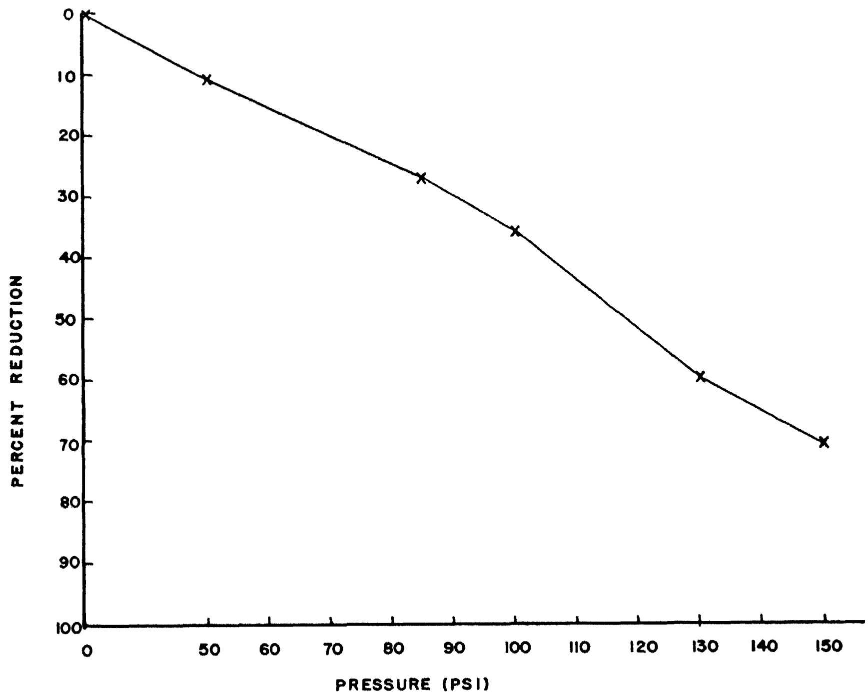


Fig. 9.—Effect of spray pressure on drosophila egg reduction

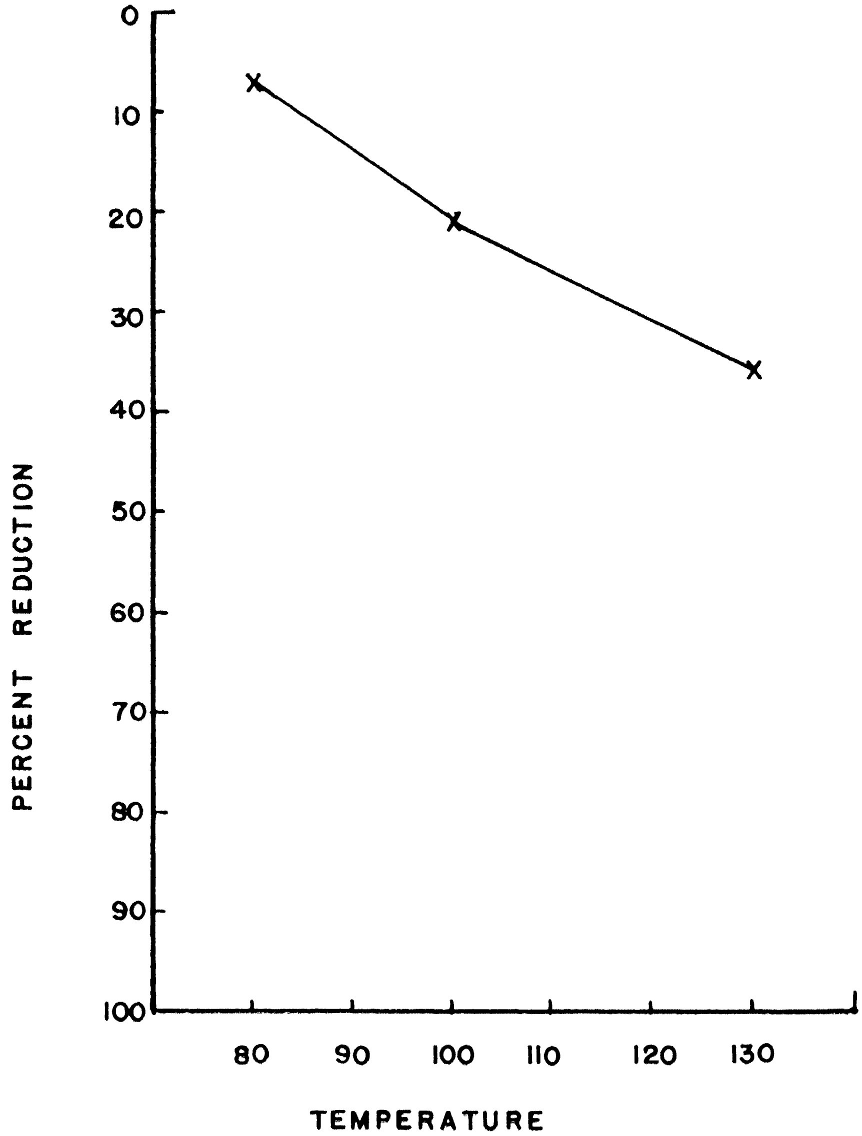


Fig. 10.—Effect of temperature on detergent efficiency (0.25% concentration).

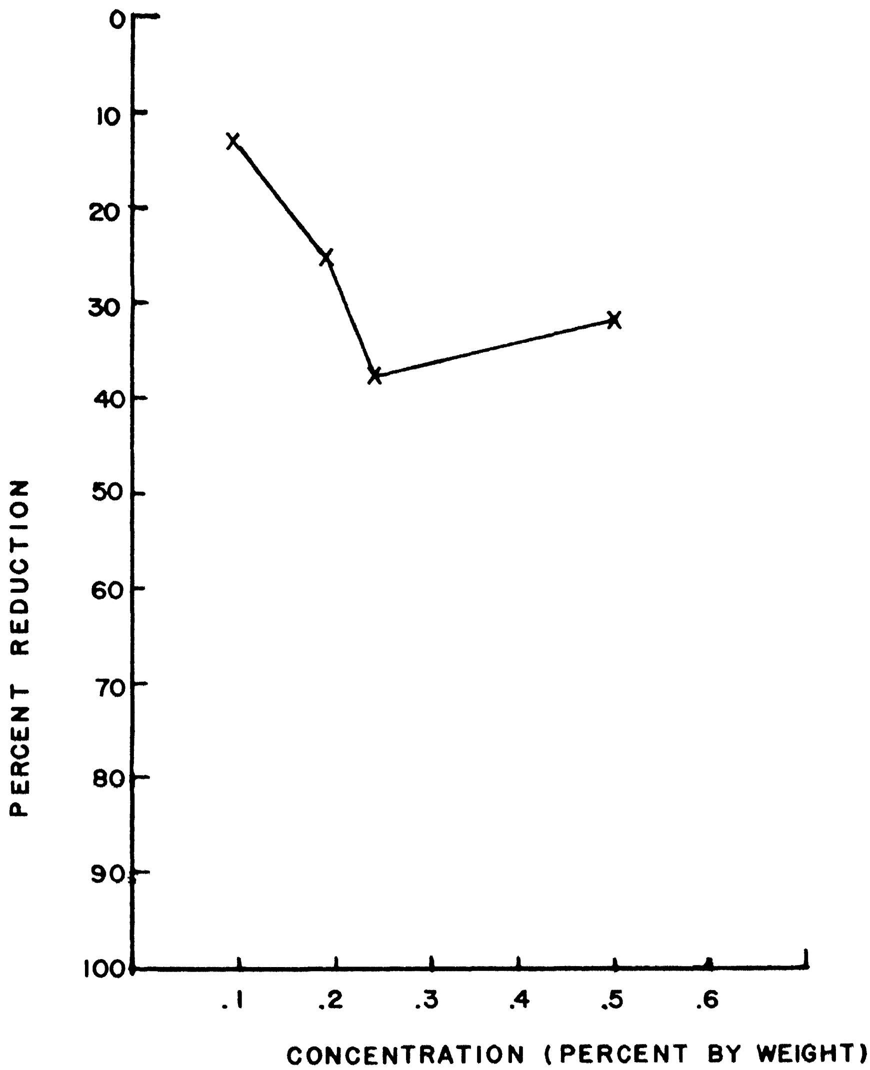


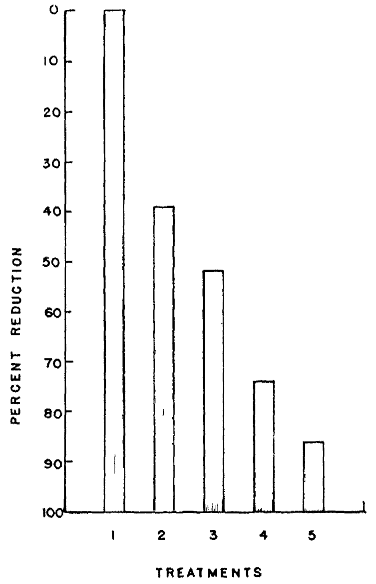
Fig. 11.—Effect of detergent concentration on drosophila egg reduction.

C. **Detergents**

As has been previously stated, detergents were studied from the standpoint of an additive when necessary. They were not necessary all the time as eggs and larvae could be removed from many tomatoes by proper washing.

During the preliminary studies on detergents, it was found that as temperature was increased the removal of eggs was increased. The trend, shown in Figure 10, varied with the formula and concentration of detergent.

After the 1955 season, a detergent was formulated to be used in the 1956 studies. It was a low-foaming granular compound. Concentrations were varied from 0.1 percent to 0.5 percent. The results obtained with this formula were shown in Figure 11. The greatest reduction was obtained at a concentration of 0.25 percent.



TREATMENT	EXPLANATION
1	COLD WATER, REGULAR SPRAYS NO AGITATION (CHECK LOT)
2	COLD WATER, HIGH PRESSURE SPRAYS
3	HOT WATER, REGULAR SPRAYS
4	HOT WATER, HIGH PRESSURE SPRAYS
5	HOT WATER, HIGH PRESSURE SPRAYS, 0.25% DETERGENT

Fig. 12.—Effect of combination of specific chemical and physical factors on drosophila egg and larvae removal.

D. Chlorine

Although the efficiency of egg and larva removal was increased as temperature increased, the possibility of thermophilic build-up might also be increased. In order to control thermophiles, a sodium hypochlorite solution was proportioned into the soak tank. Of the concentrations used, plate counts indicated that six to eight parts per million residual chlorine prevented possible thermophilic build-up. Furthermore, the flavor of the juice was not affected when chlorine was used in the soaking and spray-rinsing operations.

SUMMARY

The studies on the washing of tomatoes to remove *Drosophila* eggs and larvae were divided into two aspects. These were (1) the mechanical or physical and (2) the detergent or chemical phases.

The mechanical phase consisted of two operations; soak and spray-rinse. Three factors were considered in each of these operation. These were (1) agitation, (2) time and (3) temperature for the soak period and (1) type and number of nozzles, (2) rotation of the tomatoes, and (3) water pressures for the spray-rinse.

A summary of the effect of these factors was shown in Figure 12. It was found that tomatoes should be vigorously agitated during a three minute soak at 130° F. On the commercial line, an average reduction of 52 percent was obtained by this operation alone.

In the spray rinse operation, a nozzle which delivers a square spray pattern was used at a pressure of 130 p.s.i. The tomatoes made two complete revolutions while under the sprays. When placed seven inches above the conveyor, one square foot coverage was obtained per nozzle. By the use of high pressure sprays alone, egg and larva counts were reduced an average of 39 percent.

When these two operations were combined, that is soak and high pressure rinse, an average reduction of 74 percent was obtained. It could be said that these operations were not completely additive in their effects; however, this was probably because some of the eggs and larvae removed in the spraying operation could have been removed by the soak. Thus, a certain amount of contamination could be removed by either operation, that is there appeared to be an overlapping effect.

When detergents were added to the soak tank, the count was further reduced to 86 percent. Detergents were not necessary with some lots of tomatoes since some of the eggs and larvae could be removed from the tomatoes by the proper combination of the soaking and spray-rinsing operations.

A sodium hypochlorite solution was studied to determine the concentration necessary to prevent the possible build-up of thermophilic bacteria in the soak water when used at these elevated temperatures. It was found under these conditions that six to eight ppm. chlorine residual effectively controlled thermophiles.

Recommendations:

1. Tomatoes for processing should be soaked for three minutes while being vigorously agitated. This may be accomplished in flumes if long enough for the necessary immersion time and if agitated by air or steam. It is highly recommended that this water be made up "fresh" to prevent recontamination of the fruits. It was found that a temperature of 130° F. was most effective in the removal of *Drosophila* eggs and larvae; however, at that temperature a chlorine residual of 6 to 8 ppm. may be necessary to control thermophilic organisms. This will depend on the accumulation of "soil" or the organic matter build-up in the flume or soak tank.

2. A thorough rinsing should follow the soaking phase of washing. This rinse water should be fresh water so as not to recontaminate the tomatoes. The fruits should make two complete revolutions while under the sprays. Fullcone nozzles, which deliver a square spray pattern, should be placed seven inches above the roller conveyor. At this height, one square foot of surface is covered when pressure of 130 p.s.i. is maintained. The number of nozzles to be used is determined by the width of the conveyor and the length necessary to accomplish, at least, two revolutions of the tomato while under the sprays. There should be, at least, one nozzle for every square foot of surface.

3. Detergents should be used as an additive when tomatoes from the field have many cracks and when *Drosophila* fly activity is heavy. A concentration of 0.25 percent should be maintained in the soak tank.

4. The in-plant procedures must accompany good field control practices and good handling methods in order to control the *Drosophila* flies and thus, prevent the tomatoes and the processed tomato products from being contaminated with eggs and larvae.